

CHANGE OF PRIMARY COSMIC RADIATION NUCLEAR COMPOSITION IN THE ENERGY RANGE $10^{15} - 10^{17}$ eV AS A RESULT OF THE INTERACTION WITH THE INTERSTELLAR COLD BACKGROUND OF LIGHT PARTICLES

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In this paper the updated arguments in favor of a simple model, explaining from the united positions all peculiarities of the Extensive Air Shower (EAS) hadron $E_h(E_0)$ (and muon $E_\mu(E_0)$) component energy fluxes dependence on the primary particle energy E_0 in the primary energy region $10^{15} - 10^{17}$ eV are represented. These peculiarities have shapes of consequent distinct deeps of a widths $dE_h/E_h \simeq 0.2$ and of relative amplitudes $dL/L \simeq 0.1 - 1.0$, and are difficult to be explained via known astrophysical mechanisms of particle generation and acceleration.

In the basis of the model lies the destruction of the Primary Cosmic Radiation (PCR) nuclei on some monochromatic background of interstellar space, consisting of the light particles of the mass in the area of 36 eV (maybe the component of a dark matter) [1] - [4]. The destruction thresholds of PCR different nuclear components correspond to the peculiarities of $E_h(E_0)$. In this work the results of the recent treatment [5] of large statistical material are analyzed. The experimental results are in good agreement with the Monte-Carlo calculations carried out in the frames of the proposed model.

1 Introduction

In [1] - [4] the possibility of the existence of the Primary Cosmic Radiation (PCR) nuclei spectra cutoff effect (i.e. sharp decrease of their flux) in the energy range $> \sim 10^{16}$ eV was considered. The possibility to connect this phenomenon with the destruction of the PCR nuclei on some diffuse monochromatic background of the interstellar space consisting of the particles of the mass ~ 30 eV was discussed. In [1] the results were based on the investigation of high energy multiple muons (so called muon groups) energy behavior in cosmic ray Extensive Air Showers (EAS) as a function of N_e (EAS size) or of E_0 (primary energy of EAS initiating particle). In [2] - [4] the energy E_h of EAS hadronic component as a function of N_e or E_0 was investigated. The conclusions on the existence of PCR nuclei spectra cutoff in the N_e range $10^6 - 10^7$ particles (corresponding to the primary energy range of the order of $10^{15} - 10^{16}$ eV) were confirmed.¹ So the two different manifestations of the same phenomenon were fixed by means of two different installations using completely different methods.

In the present work the results of the recent treatment of large archive statistical material, carried out in [5], are analyzed. The data were obtained by means of multilayer ionization calorimeter (the area of each layer 36 m^2) of

¹We will not discuss here the other, in principle possible but rather unnatural mechanisms to explain such a structures in spectra.

the Tian- Shan high mountain installation in the period before 1980, and were retreated anew in the frames of the new approach. The work [5] was aimed at investigation of EAS hadronic component energy using different statistical material, obtained at different configurations of the installation, at different triggering conditions and different selection criteria. Usage of an improved approach to the data handling enabled us to establish the EAS parameters with sufficiently high precision and to increase the $E_h(N_e)/N_e$ dependence irregularities detection reliability and the accuracy of their localization along the N_e (or E_0) axis.

We will show that all these peculiarities may be naturally connected with the main groups of PCR nuclei spectra consequent cutoff process as a result of their destruction on some monochromatic diffuse background of interstellar space and with the accumulation of the products of this destruction.

In section 2 we give the brief description of the main principles of the analysis. In sections 3 and 4 the obtained experimental results are discussed, the main parameters of the model and the results of Monte-Carlo calculation of the observed effects made in the frames of the proposed model are given.

2 The experimental data and the basic principles of the analysis

As it was shown in [2] -[4] the experimentally observed dependence of EAS hadronic component energy E_h on EAS size N_e has noticeable peculiarities of behavior.

The results of the last updated treatment of the large statistical material (more than 350 000 handled events in total) are reproduced from [5] in Fig. 1.

On this Figure are represented the specific energies $E_h(N_e)/N_e$ of the EAS hadronic component, obtained at the different configurations of the experimental apparatus and at different selection criteria. For details see [5].

The lower borders by N_e are determined by the material available to-day and by triggering conditions (curves 1,4 and 5), or by conditions of preliminary selection (curves 2 and 3). The upper borders are determined by statistical restrictions due to the high steepness of the EAS spectrum $I(N_e)$. The error bars allow for statistical errors. The errors of N_e determination are of the order of 10%. The difference of mean slopes of the curves to the left from the values $N_e \sim 10^6$ is easy to explain by the difference in triggering conditions and in the selection criteria. The solid curves (splain), are drawn through the experimental points.

On all the presented curves in the region of $N_e > 5 \cdot 10^5$ the series of deeps with decrease of E_h are clearly seen. Most clearly these irregularities are revealed in the region $N_e > 2 \cdot 10^6$, where the identical localization of these phenomena on all shown curves may be easily traced. The indicated deeps in $E_h(N_e)/N_e$ dependence are located in the regions of the same values of N_e , regardless of experimental material used and of triggering and selection conditions (curves 1,2 and 3). Moreover, the localization of these deeps does not depend on the zenith angle of the event registration (curves 4 and 5 - the angles $0^\circ - 20^\circ$ and $20^\circ - 30^\circ$ respectively).

In the region of relatively low values of N_e , namely at $5 \cdot 10^5 < N_e < 2 \cdot 10^6$

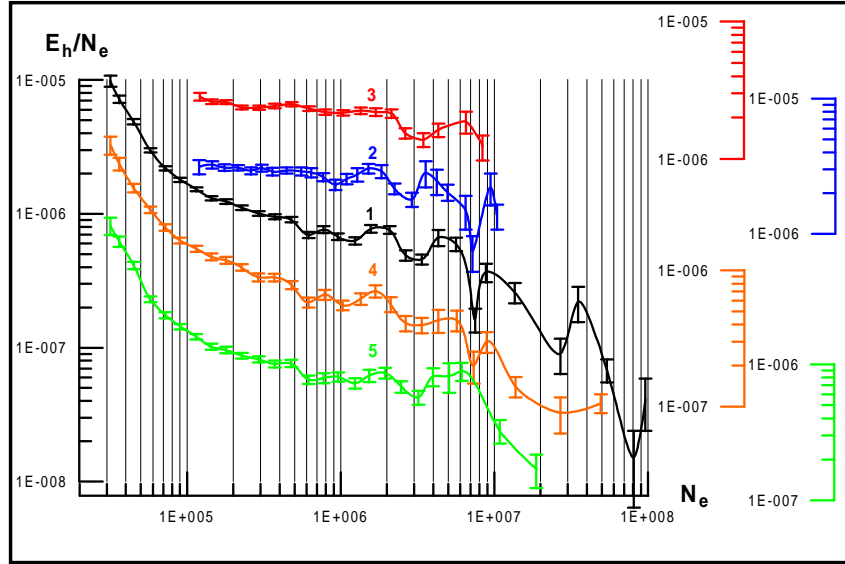


Fig.1 : The specific energies $E_h(N_e)/N_e$ of the EAS hadronic component for the different configurations of apparatus and selection conditions. Details are given in the text and in [5]. The left vertical scale (arbitrary units) is given for curve 1. The other curves are slightly shifted up or down to separate them from one another and to clarify the picture. The corresponding parts of vertical scales are shown at the right edge of the figure.

the mutually equivalent irregularities may be seen as well. Here, however, a further increase of accuracy and of statistics is required. In the region $N_e < 5 \cdot 10^5$ at this stage of investigation the $E_h(N_e)/N_e$ dependence behavior is revealed as completely smooth. The very last deep on the curve 1 is not provided statistically.

Actually, here we are dealing with the results obtained in the several independent experiments.

Apparently the sufficiently natural explanation for the creation of such behavior of EAS hadronic component energy flux, proposed by us in [1],[3] is based on the existence of PCR nuclei spectra consequential cutoff in the primary energy region $> 10^{15}$ eV. The destruction of PCR nuclei is caused by their interactions with some light particle (maybe the component of a dark matter, since the neutrino does not match this role due to its parameters) forming the monochromatic, low temperature background in interstellar space.

The results of the calculation of $E_h(N_e)/N_e$ dependence based on this model are presented in Fig.3 and are discussed in section 4.

According to this model, the cutoffs of PCR nuclei spectra have a threshold character and depend on the primary energy of the nucleus and on the energetic threshold of its destruction. For the heavy nuclei of Fe group this phenomenon takes place at N_e -s higher then $\sim 7.4 \cdot 10^6$, which corresponds to primary energies of the order of $1.4 \cdot 10^{16}$ eV. At the energies higher then $\sim 4 \cdot 10^{16}$, at which the nuclei of Pb group are destroyed, the protons are dominant in the PCR, with the exception of some part of survived nuclei and of the heaviest nuclei like uranium. The latter are destroyed at the higher energies.

The essence of the deep formation mechanism on $E_h(N_e)/N_e$ dependence was given in [5]. We reproduce it here with some additional details. The sketch illustrating this mechanism is given in Fig.2.

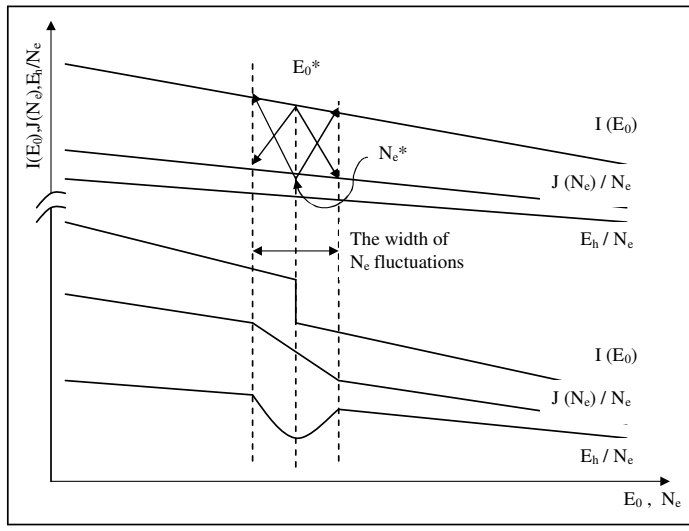


Fig.2 : The sketch to explain the mechanism of deep formation

The EAS of the certain given N_e^* are generated by the primary particles of the energy wedged within a rather wide interval of primary energies E_0 . There is some balance of the contributions of these E_0 , which depends on the slope of the primary energy spectrum. On the other hand, at a fixed value E_0^* of primary particle energy, the number N_e of particles in EAS fluctuates within a rather wide range with the certain mean value N_e^* .

Let the spectrum of the given certain component of PCR have the form $I(E) = K \cdot E^{-r}$. Now let the spectrum of this component of PCR be cut off above some fixed value of primary energy E_0^* (cutoff energy), i.e. at primary energies higher then E_0^* the flux of this component of PCR sharply decreases (the value of coefficient K falls sharply). However, it is clear from the above that the spectrum of the corresponding EAS will not be cut off above the value N_e^* since the showers from primary particles of the energies $E_0 < E_0^*$ will still be registered due to fluctuations of N_e in the showers of total energy $E_0 < E_0^*$. The showers initiated by the primary particles (of the PCR component under consideration) of the energy $E_0 > E_0^*$ will be present in extent of the new value of coefficient K .

It is established that the mean energy flux E_h of hadrons rises in average with the rise of E_0 (i.e with the rise of N_e). Besides, at the fixed energy E_0 the anticorrelation of E_h and N_e fits naturally with the account of the approximate conservation of the sum of e - and h -component energies. It follows here from, that in the case of spectrum cutoff the flux of hadron energy in EAS of $N_e > N_e^*$ will decrease on average as compared with the case of the absence of cutoff, since the EAS for such N_e -s now will be generated by the primary particles of the energies $E_0 < E_0^*$. The balance of contributions in showers of some given N_e generated by primary particles of different energies will be upset. The width of the interval in which this effect does occur will be of the order of width of the fluctuations of N_e . At higher N_e -s exceeding the frames of this interval, all manifestations of the flux of this component will decrease sharply, and the spectrum of showers from this component will fall as well. However, above the indicated interval the balance of contributions is restored (because the spectrum has the same slope again) and the mean energy of hadrons in EAS (not the intensity of EAS!) reaches its previous level. In the case of complete cutoff of the spectrum EAS from this component will vanish completely. For the mixed composition of PCR the spectra of different components will be cut off at

different E_i^* -s (i - indexes of the components) [3] and one has to expect deeps on the $E_h(N_e)/N_e$ plot near the corresponding values of N_e - s. The widths of these deeps are determined by the ranges of N_e fluctuations.

In the region of $N_e < N_e^*$ the upset of the balance of contributions to showers of given N_e will take place as well. Actually, in the absence of the cutoff effect the EAS of the primary energy $E_0 > E_0^*$ are also contributing to this region of N_e . In case of the cutoff of the spectrum of a given component this balance will be upset as well. The width of the interval to the left of N_e^* where this effect occurs is also of the order of N_e fluctuations. However, this effect will be essentially less than the above considered one (due to the steepness of the spectrum).

This mechanism of $E_h(N_e)/N_e$ dependence formation is analyzed in [3], where the principles and results of the calculation of the expected features of this dependence are given. It is to be noticed however, that the level of data processing and analysis in [3] was lower then reached to day, so the numerical values of the model parameters and the localization of the signals along the N_e axis differ remarkably from the present results.

From the above presented qualitative description of the process, it follows that the position of the deeps on the $E_h(N_e)/N_e$ dependence along the N_e scale is determined by the PCR nuclei threshold energies E_0^* , necessary to switch on the mechanism of nuclei destruction on the particles of interstellar monochromatic background. The threshold energies of PCR nuclei destruction are determined by kinematics of PCR nuclei destruction in the interactions with the interstellar monochromatic background particles of mass m

$$A_0 + x = A_1 + A_2 + x' \quad (1)$$

where A_0 is initial nucleus of PCR , x - background particle in the initial state, A_1 and A_2 - nuclei-fragments of destructed primary particle, x' - background particle in final state.

For simplification we consider basically the 2-particle destruction channels of nuclei, and besides they require the least amount of energy transfer.

The threshold energy $E = E_0^*$ for reaction(1) in the rest system of x -particle is determined by the minimal value of $S_0 = M_0^2 + m^2 + 2Em$, where M_0 and E - are the mass and the energy of the initial nucleus, consequently by the minimal invariant value of $\omega^* = E \cdot m$, at which the reaction (1) can take place.

The invariant threshold ω^* of the reaction (1) is determined by the properties of the nucleus and its fragments - by masses, binding energies etc. If M_0 - is the mass of the initial nucleus, M_1 and M_2 - masses of nuclei- fragments, while m - the mass of the background particle, then it is easy to show that the reaction (1) can take place only under the following condition

$$E > E^* = \omega^*/m = 1/2 \cdot [(M_1 + M_2)^2 - M_0^2] \quad (2)$$

which with good approximation may be written down in the more convenient form

$$E > E^* = \omega^*/m = (M_0/m) \cdot \delta \quad (3)$$

where $\delta = M_1 + M_2 - M_0$.

So, at the fixed mass m of the background particle these threshold cutoff energies for starting of the destruction process of different nuclei and for the

different channels of the reaction (1) will be proportional to the corresponding invariant thresholds. Naturally a sufficient degree of nuclei destruction is necessary to form signals on the $E_h(N_e)/N_e$ dependence - see section 3.

To calculate the value of average hadron energy flux $E_h(N_e)$ in the EAS of fixed particle number N_e it is natural to use the simultaneous possibility distribution of E_h and N_e in EAS at the fixed initial energy E_0 . One can use any distribution providing it corresponds with the EAS phenomenology established for to day. Let $P_i(E_h, N_e|E_0)$ - be the density of such distribution for EAS of the initial energy E_0 , where $i = 1, 2, 3, \dots, M$ - indicates one or another component of PCR, i.e. the kind of nucleus under consideration. Then for the case of M kinds of PCR the mean energy of the EAS hadronic component may be presented as the average of specific mean energy fluxes. It may be calculated under different assumptions on the behavior of PCR separate components, in particular at the presence of the cutoff process of these spectra at some threshold energies. The version of such calculation using the lognormal distribution as $P_i(E_h, N_e|E_0)$ is described in [3]. In the same work the analytically calculated shape of $E_h(N_e)$ distribution is presented, matched to the results obtained at that time.

In this work we present the results of new calculations carried out by means of the Monte-Carlo method (as one more corresponding to the character of the task) based on the model proposed.

3 The analysis of nuclei destruction chains

Let us return now to Fig. 1, where the results of the work [5] are reproduced. They are represented in the form $E_h(N_e)/N_e$, i.e. the value of EAS hadronic component energy flux per one electron of EAS. As was said above, on all of the given curves the deeps are clearly seen, located at the same values of N_e . These deeps we bring further into correspondence with the PCR nuclei destruction, considered in section 2.

The consideration we'll carry out uses the curve 1 as one mostly provided statistically and covering the widest diapason of the EAS sizes N_e (i.e. of E_0).

At the first stage of consideration it will be natural to choose the nucleus of a Fe as a bench-mark nucleus, the destruction area of which $E_0 \sim 2 \cdot 10^{16}$ eV was estimated in [1] most reliably. The choice of Fe nucleus is determined also by the fact that it is represented in PCR in a sufficiently large amount at lower energies and so its destruction signal must distinctly stand out against the background of the neighbor nuclei. And what is very important, the fluctuations of N_e in EAS initiated by Fe nuclei are smaller than in those initiated by more light nuclei. For these reasons the signal of Fe destruction must be less diffuse as compared with the signals of the other nuclei or their groups. On the strength of the aggregate of these indications the deep with the minimum at $N_e = 7.4 \cdot 10^6$ was taken as a signal of Fe destruction (the corresponding value of E_0 is $\sim 1.4 \cdot 10^{16}$ eV). It may be distinctly seen on the curves 1, 2 and 4. On the curves 3 and 5 these ranges of N_e - s are not provided with the statistical material. It is natural to take for the N_e , corresponding to the threshold energy of Fe destruction, the value $N_e = 7.4 \cdot 10^6$ where the signal under consideration has a minimum. The location of N_e threshold value, in the minimum point of the signal, obviously follows from the above given qualitative description of the process.

Taking the indicated point as a bench-mark, and with account of the value

of lowest invariant threshold of Fe destruction, one can evaluate the mass of the background particle on which the destruction of Fe nuclei takes place.

Here however one must take into account the necessity of the achievement of a sufficient degree of nuclei destruction, to let the heaviest fragments be shifted far enough to the left from the threshold energy of the initial nucleus. The value of this shift must provide the exit of the signal area out of the limits of possible N_e fluctuations in EAS, caused by the most massive fragments at the end of the destruction chain. This is necessary to exclude all traces of the influence of destructed nuclei and their fragments on $E_h(N_e)/N_e$ dependence formation in the region of the signal. Without this, the above described mechanism of signal creation on $E_h(N_e)/N_e$ dependence will work less efficiently. Assuming maximum possible fluctuations have the value $\sim 50\%$ (including the measurement error) one can conclude that the mass of the heaviest fragment must not exceed the value of about 0.5 of the mass of the initial nucleus. In the case of Fe this corresponds to the nucleus of Si28.

Now it is easy to extract the value of the background particle mass $m = 36.76$ eV (in [3] we represented the value of $m \sim 36.4$ eV) which provides the existence of the whole chain of destructions from Fe56 down to Si28, started from the above indicated experimental value of $N_e = 7.4 \cdot 10^6$ for the Fe56 destruction signal ($E_0 = 1.42 \cdot 10^{16}$ eV). In reality, under these conditions the much deeper continuation of the destructions chain is automatically provided. Note, that by approaching the indicated value of E_0 , more and more deep consequent links of the destruction chain are joining to it, resulting in noticeable flattening of the left fronts of the signals, which can be clearly seen on the experimental curves. The steepness of the right front is noticeable higher. It is determined by the steepness of the spectrum cutoff and by the accuracy of measurements, of course.

After this, proceeding from the obtained value of m and from the invariant destruction thresholds of the other nuclei, it is easy to distribute the areas of their destruction along the N_e scale (providing corresponding chains of destructions). The result is shown on Fig. 3. The vertically downwards directed arrows symbolize the destruction regions of main stable nuclei of PCR from He4 to Fe56. It must be noted that such a correspondence between the PCR and signals on the $E_h(N_e)/N_e$ dependence turn out to be the best one. In any other version the level of correspondence becomes explicitly unacceptable.

The numeric values of the nuclei destruction thresholds, as well as the threshold values of N_e and E_0 for the basic nuclei of PCR, are quoted in Table 1. The data for some of the light nuclei are quoted as well.

Note that for all nuclei quoted in Table 1, the energetic thresholds for the destruction down to fragments of the mass $M < \sim 0.5 \cdot M_0$ provide the destruction down to He4 as well. The values of the masses for the nuclei A_0 , A_1 and A_2 , entering the expression (1) are calculated in accordance with the Tables of Atomic Masses [6]. For the heavy nuclei of the Pb the calculation was made approximately. The invariant threshold of N14 destruction, for which the binding energy per nucleon (7.7 MeV) is close to corresponding value for Pb (7.9 MeV), was assumed as a basis and then the correction was allowed proportional to the relation of the mean binding energy and of the masses of these nuclei.

NUCLIDE	FIRST LINK OF THE LOWEST DESTRUCTION CHAIN	NUMBER OF DESTRUCT. STEPS	THE INVARIANT THRESHOLD OF THE LOWEST CHANNEL (eV)	THRESHOLD ENERGY E_0^* OF DESTRUCTION TO FRAGMENTS OF THE MASS $M \sim 0.5 M_0$ (eV)	THE CORRESPONDING SIZE N_e OF THE ACCOMPANYING EAS	THE SHARE (%) IN PCR, ACCEPTED BY CALCULATIONS	E_0^* / M_0 (eV)	THE ENERGY OF CREATED He 4 NUCLEI (eV)	N_e IN EAS FROM THE CREATED He 4 NUCLEI
H1		1				20			
He4	H1 + T3	1	$7.41 \cdot 10^{13}$	$2.02 \cdot 10^{15}$	$7.84 \cdot 10^5$	10	$0.50 \cdot 10^{15}$		
C12	He4 + Be8	1	$8.24 \cdot 10^{13}$	$2.24 \cdot 10^{15}$	$8.86 \cdot 10^5$	6	$0.19 \cdot 10^{15}$	$0.75 \cdot 10^{15}$	$2.51 \cdot 10^5$
N14	H1 + C13	2	$9.85 \cdot 10^{13}$	$2.68 \cdot 10^{15}$	$1.09 \cdot 10^6$	4	$0.19 \cdot 10^{15}$	$0.77 \cdot 10^{15}$	$2.58 \cdot 10^5$
O16	He4 + C12	2	$1.07 \cdot 10^{14}$	$2.99 \cdot 10^{15}$	$1.23 \cdot 10^6$	14	$0.19 \cdot 10^{15}$	$0.75 \cdot 10^{15}$	$2.51 \cdot 10^5$
Mg24	He4 + Ne20	4	$2.08 \cdot 10^{14}$	$5.66 \cdot 10^{15}$	$2.57 \cdot 10^6$	8	$0.24 \cdot 10^{15}$	$0.94 \cdot 10^{15}$	$3.28 \cdot 10^5$
Al27	He4 + Na23	4	$2.54 \cdot 10^{14}$	$6.90 \cdot 10^{15}$	$3.23 \cdot 10^6$	8	$0.26 \cdot 10^{15}$	$1.02 \cdot 10^{15}$	$3.59 \cdot 10^5$
Si28	He4 + Mg24	5	$2.60 \cdot 10^{14}$	$7.08 \cdot 10^{15}$	$3.33 \cdot 10^6$	8	$0.25 \cdot 10^{15}$	$1.01 \cdot 10^{15}$	$3.55 \cdot 10^5$
Fe56	He4 + Cr52	12	$3.97 \cdot 10^{14}$	$1.42 \cdot 10^{16}$	$7.38 \cdot 10^6$	16	$0.25 \cdot 10^{15}$	$1.01 \cdot 10^{15}$	$3.55 \cdot 10^5$
Pb208				$3.92 \cdot 10^{16}$	$2.38 \cdot 10^7$	5	$0.19 \cdot 10^{15}$		
D2	H1 + n	1	$4.18 \cdot 10^{12}$	$1.14 \cdot 10^{14}$	$2.88 \cdot 10^4$				
He3	H1 + D2	1	$1.55 \cdot 10^{13}$	$4.20 \cdot 10^{14}$	$1.29 \cdot 10^5$				
Li6	He4 + D2	1	$8.24 \cdot 10^{14}$	$2.24 \cdot 10^{14}$	$6.28 \cdot 10^4$		$0.37 \cdot 10^{14}$	$0.15 \cdot 10^{15}$	
Li7	He4 + T3	1	$1.61 \cdot 10^{13}$	$4.39 \cdot 10^{14}$	$1.36 \cdot 10^5$		$0.63 \cdot 10^{14}$	$0.25 \cdot 10^{15}$	
Be9	n + Be8	1	$1.40 \cdot 10^{13}$	$3.80 \cdot 10^{14}$	$1.15 \cdot 10^5$		$0.42 \cdot 10^{14}$	$0.17 \cdot 10^{15}$	
B10	He4 + Li6	2	$4.16 \cdot 10^{13}$	$1.13 \cdot 10^{15}$	$4.04 \cdot 10^5$		$1.13 \cdot 10^{14}$	$0.45 \cdot 10^5$	

Table 1

From Table 1 it can easily be seen that for the majority of nuclei the threshold values of N_e may be divided into groups disposed on the graph near the areas of the main peculiarities of the $E_h(N_e)/N_e$ dependence. Division into such groups can be easily explained by the influence of the periodicity (oscillations) in the dependence of alpha-particles binding energy in the nucleus on its mass. The groups are formed by nuclei with the close values of the quantity $E^* = \omega^*/m$. The obtained value of the background particle mass can be expressed as

$$m = 36.76 \pm (10 + 5)\% \text{ eV}$$

Here the value in parenthesis is the sum of systematic error, determined by the accuracy of the transition from the experimental value of the particle number N_e in EAS to the energy E_0 of the initial nucleus (evidently it is of the order of 10 %) and of the statistical error, not exceeding $\sim 5\%$.

In articles [1] and [3] we presented the value of m of the order of 30 eV and 36.4 eV. The refinement of the signal localization along the N_e axis and usage of the new approach led to a close value of m .

It must be noted however, that there are not any peculiarities corresponding to the destruction of nuclei of B10, Be9, Li6, Li7 and most light nuclei of He3 and D. It can be the result of a too small amount of these nuclei in PCR, which is below the resolution level limit achievable at the recent stage of data treatment. It would be extremely interesting and important to fix the signals of He3 in the N_e region $\sim 1.3 \cdot 10^5$, B10 in the N_e region $\sim 4 \cdot 10^5$ and especially D2 in the N_e region $\sim 2.9 \cdot 10^4$, which must be located on the graph completely apart from the other nuclei. The discovery at least of some of these signals would confirm the above described effects with very high reliability. The efforts to increase the precision level of the information extraction are now in progress and seem to have realistic prospects.

4 Monte-Carlo calculation of the disturbed flux of hadron energy

In Fig.3 the result of the Monte-Carlo calculation of $E_h(N_e)/N_e$ dependence, carried out in the frames of the proposed model, is shown. The nuclei from Table 1, as those most abundant in PCR, are included in the calculation. The shares of the nuclear components in PCR, accepted by the calculations, are also given in Table 1. For the fluctuations of N_e and E_h in EAS, initiated by these nuclei, the values respectively 25% and 100% are accepted. Note that in the value of E_h fluctuations not only the necessity of energy balance conservation between the EAS components contributes, but the variation of the mean longitudinal momentum as well, which results in the variation of the secondary hadrons front cone and consequently in the variation of the density of hadron flux through calorimeter. As a result the hadron energy flux through the calorimeter fluctuates more sharply. It is obvious from Fig.3, that the proposed model easily and naturally leads to the observed effect.

As can be seen from Table 1, to destruct any of the quoted nuclei only about one collision with the transfer of required energy per each 4 nucleons of the nucleus is needed. So as a condition of the process under consideration one

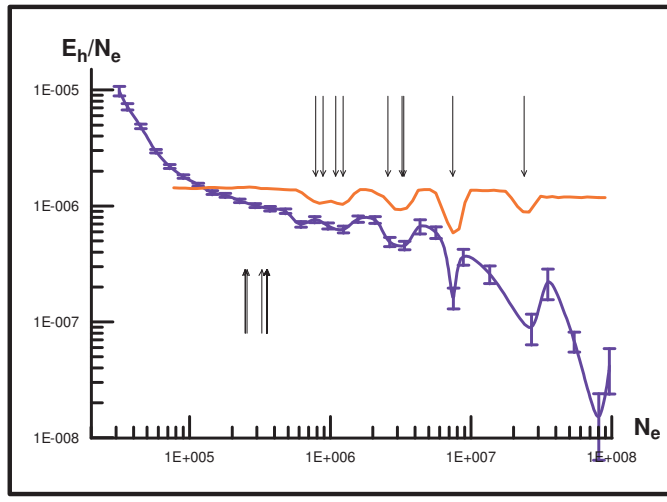


Fig.3 : The blue curve and the downward directed arrows - the correspondence between the deeps on the dependence $E_h(N_e)/N_e$ and the thresholds of PCR nuclei destruction. The upward directed arrows - the low energy border of the area of PCR nuclei fragments accumulation. The red curve - the Monte-Carlo calculation of the dependence $E_h(N_e)/N_e$ in the frames of the proposed model.

can write

$$\sigma = n \cdot (L \cdot \rho)^{-1} cm^{-2}, \quad (4)$$

where $n = 0.25$ is the number of the effective collisions per nucleon of the nucleus, L is the length of the nucleus propagation in space, ρ is the density of background particles in space, σ is the cross-section of nucleon interaction with the background particle.

This order of cross-section seems to be the optimal one, because at $n = 1$ all nucleons (including the singles) will interact at least once, which would lead to the PCR spectrum cut off already at the energies of the order of 10^{17} eV due to the energy losses of nucleons caused by multiple production of pions on background particles. (The process analogous to GZK process, which takes place at the energies $> \sim 5 \cdot 10^{19} eV$). In case of the cross-section written above only of $\sim 25\%$ of protons will be involved in the process. This process, together with the nuclei destruction and accumulation of their fragments at lower energies can lead to the experimentally observed steepening of primary spectrum at the energies $> \sim 4 \cdot 10^{15} eV$.

In this connection one has to note the following circumstance as well. The majority of the lowest invariant channels are those with the separation of the alpha - particle. It is important to notice as well, that at the described process of nuclei destruction the specific energy per one nucleon of the nucleus is practically preserved. As can be seen from Table 1, the specific threshold energy of He4 destruction is about 2 - 3 times higher than that of the other nuclei. From here it is easy to see that He4, generated as a result of the destruction of heavier nuclei at the energies not exceeding the corresponding thresholds more than about 2 - 3 times, will not be destroyed at the consequent impacts with the background particles. The whole of this He4 will be accumulated in the area of lower energies, determined by the relation between the masses of He4 and the destructed nucleus (see the last column of Table 1). This low energy border

of the fragment accumulation area of all the nuclei participating in the process is shown in Fig.3 by upward directed arrows. However, due to high steepness of the energy spectrum and dispersion of fragments by the energy we have no effects of threshold character here, and the expected influence on the shape of $E_h(N_e)/N_e$ dependence is weak. Nevertheless, despite the smooth character of fragment accumulation, their amount in the accumulation area can reach up to $>\sim 5\%$ of the primary spectrum according to the preliminary evaluation, and one can expect the influence of this process on the shape of the spectrum. It is not excluded that namely the aggregate of all these processes, including the accumulation of the fragments of destructed nuclei, leads to the macro effect - the well known peculiarities of the primary spectrum in the energy region $10^{15} - 10^{17}$ eV - the so called bump on the primary spectrum in the area $\sim 10^{15}$ eV and the change of PCR spectrum slope in the consequent region. Preliminary calculation leads to qualitative accordance with the observed shape of the primary spectrum.

5 Conclusions

In conclusion let us formulate the main obtained results.

- The experimentally observed irregularities of the EAS muon (muon groups) [1] and hadron [2] - [5] components energy dependence on the energy of the initial particle, can be naturally treated as a result of PCR nuclei spectra cutoff in the primary energy region $10^{15} - 10^{17}$ eV.
- These irregularities are difficult to explain by means of the ordinary astrophysical mechanisms, because the contributions from the different sources of cosmic rays will "slur over" all small irregularities of the spectrum.
- From our point of view, the most attractive model is one where this effect is a result of nuclei destruction caused by their interaction with some monochromatic background of interstellar space, consisting of the particles of the mass m in the area of 36 eV.
- The Monte-Carlo calculation of the $E_h(N_e)/N_e$ dependence based on the proposed model gives satisfactory accordance with the experiment. The calculation was performed without account of the particular properties of the apparatus. To simplify the calculations we admitted, that the mechanism of nuclei destruction on interstellar monochromatic background is determined by threshold expressions $E^* = \omega^*/m$, where ω^* is the invariant threshold of initial nuclei destruction by collisions with the background particle of the mass m . At the same time the dependence of process cross-sections on the energy was ignored. In other words we considered the distance L from sources to Earth much larger than the mean path of nuclei for interaction with background particles "m". We considered the interaction with "m" - particles as a local one, and not differing between neutrons and protons, and so kinematically similar to low energy lepton-nuclear interactions.

So the minimal condition of the cross-section of this process is:

$$\sigma = n \cdot (L \cdot \rho)^{-1} cm^{-2} ,$$

where $n = 0.25$ is the number of the effective collisions per nucleon of the nucleus, L is the length of the nucleus propagation in space, ρ is the density

of background particles in space, σ is the cross-section of nucleon interaction with background particles.

Let us evaluate the order of value σ . For $m \approx 30$ eV the maximum admissible $\rho = 30 - 40$ particles per cm^3 from the restrictions on the density of the dark matter, not exceeding the value $1 - 1.5$ KeV per cm^3 . The maximum realistic $L = 3 \cdot 10^{17} sec \cdot 3 \cdot 10^{10} cm/sec = 10^{28} cm$ corresponds to 0.1 of the Universe age. So we have $\sigma > n \cdot (10^{28} \cdot \rho)^{-1} \approx 10^{-3}$ mb. If one supposes the possibility of the accumulation of these particles in the Galaxy, then one can increase in principle the density ρ not more than by 3 orders (starting from the mean size of galaxies and from the mean distances between them). This however will lead to more rigid restrictions on the radiation life time, at least by 1 order. This means, that even at these conditions the value of σ will be $\sim 10^{-4} - 10^{-5}$ mb. This is a sufficiently large value, so the processes with the participation of "m" - particles would be observed in the acceleration experiments with high probability. However, to date this has not taken place. If the above discussed interpretation of experimental results is correct then the "m" - particle has to be a neutrino-like particle. However the massive one (of the type of the 4-th generation of neutrino), participating only in the processes with neutral currents.

- The macro effect probably caused by the aggregate of the described processes - nuclear spectra cutoff and shift of the particles by energy - is the so called bump on the primary spectrum in the energy region of the order of $3 \cdot 10^{15}$ eV and the steepening of the spectrum in the consequent diapason of the energies.

- If the approach proposed in this work is correct, then the further increase of the statistics and of the data handling precision will possibly allow us to try to fix the destruction signals of B10, Be9, He3 and especially of D2. The weak signals of Li6 and Li7 may be possibly observed from the channel of their destruction down to He4 (the mass of He4 accounts for more than 50% of the mass of Li6 and Li7, and because of that the signals of their destruction will not be so clear). The threshold energies of the above listed nuclei destruction differ sharply from those for other nuclei, and because of that the signals of their destruction are located apart on the axis of primary energies (or N_e axis). The discovery at least of some of these signals would give us the additional bench mark which will allow estimating the value of the background particle mass with higher reliability and precision. The expected places of these signals on the N_e scale (with the accuracy of $\sim 15\%$, determined by the accuracy of $N_e \longleftrightarrow E_o$ transition) are $N_e \sim 1.3 \cdot 10^5$ for He3, $N_e \sim 1.15 \cdot 10^5$ for Be9, $N_e \sim 4 \cdot 10^5$ for B10 and $N_e \sim 2.9 \cdot 10^4$ for D. The expected area of the location of the comparatively weak signals of Li6 and Li7 are $N_e \sim 6.3 \cdot 10^4$ and $N_e \sim 1.4 \cdot 10^5$ respectively.

The above given evaluation of the cross-section of the interaction with background particle makes it in principle possible for generation of the signals from the next energetic channels of destruction. However for the statistics available to date, the probability of extracting these signals or of observing the fine structure of the signals from the groups of nuclei i.e. to extract the signals of the separate nuclei inside the groups (or subgroups of the groups) of nuclei is small, though some indication of the existence of such a structure can be seen on the signal of C,N,O group in the region of $N_e \sim 6 \cdot 10^5 \div 10^6$ (curve 1 in fig 1).

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